

ReNeW/HEDLP

Research Needs Workshop/High Energy Density Laboratory Plasmas

- Called jointly by NNSA and OFES - pick up where FESAC left off
 - FESAC, chaired by R Betti “Advancing the Science of High Energy Density Laboratory Plasmas”
- Modeled after the BES Basic Research Needs Workshops
- Held in Rockville, MD November 15-18, 2009
- Chaired by Bob Rosner (U Chicago) and Dave Hammer (Cornell)
- Goals
 - As recommended by the FESAC report, SC/OFES and NNSA/DP are jointly sponsoring this Workshop with the goal of examining these research opportunities in depth and deliberating on the research needs in order to pursue these opportunities. The workshop output will be a concise authoritative report suitable for wide distribution. The report of the Workshop will provide technical input to be used as guidance in strategic planning for the joint program in HEDLP by OFES and NNSA.

Panels

- High Energy Density (HED) hydrodynamics,
 - Nonlinear optics of plasmas
 - Relativistic HED plasma and intense beam physics
 - Magnetized HED plasma physics
 - Radiation-dominated dynamics and material properties
 - Warm dense matter
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- Cross-cutting issues: overall multi-aspect
 - Cross-cutting issues: diagnostics
 - Cross-cutting issues: computing
 - Cross-cutting issues: research infrastructure
 - Cross-cutting issues: High-Z, multiply-ionized HED atomic physics

Warm Dense Matter

Panel Outbrief

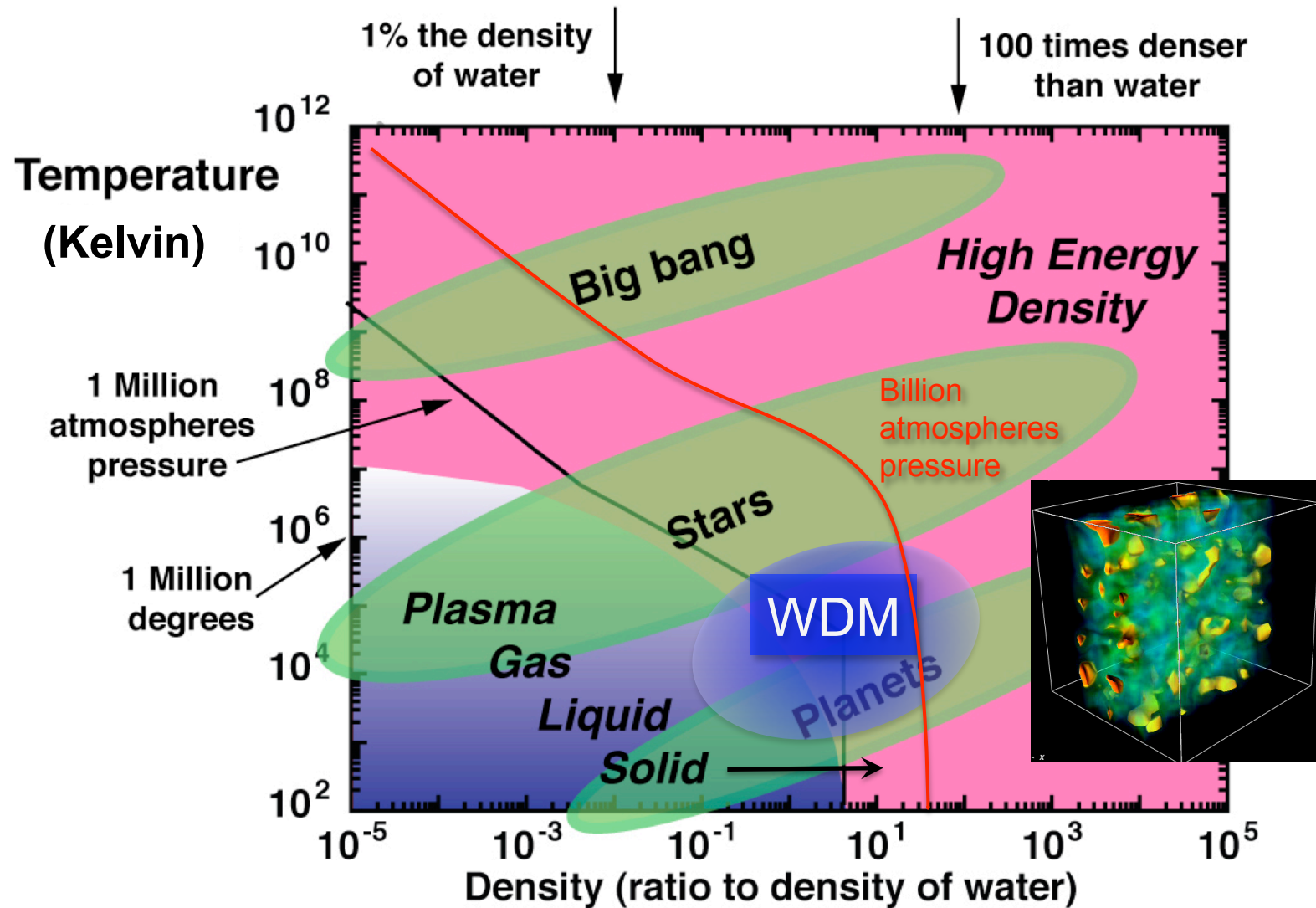
J. Benage (LANL)
L. Benedict (LLNL)
M. Desjarlais (SNL) (*lead*)
T. Duffy (Princeton)
J. Eggert (LLNL)
F. Graziani (LLNL)
Y. Gupta (Washington State U)
R. Jeanloz (UC Berkeley) (*co-lead*)

M. Knudson (SNL)
R. Lee (LBNL/LLNL)
G. Logan (LBNL)
R. More (LLNL ret.)
R. Redmer (Rostock)
D. Saumon (LANL)
S. Trickey (U Florida)

High Energy Density Laboratory Plasmas
Research Needs Workshop

Rockville, MD Nov. 15-18, 2009

Warm Dense Matter



Why are we interested?

- Violent formation of planets – *platforms for life*
 - late-stage giant impacts, Moon formation
 - evolution of planets, magnetic fields
- Path to stars – *nuclear ignition*
 - giant to supergiant planets (exoplanets) to brown dwarfs
 - path to ignition in the laboratory
- Extreme chemistry
 - Periodic Table transformed
 - “hot ices” (molecular systems), alloys and compounds

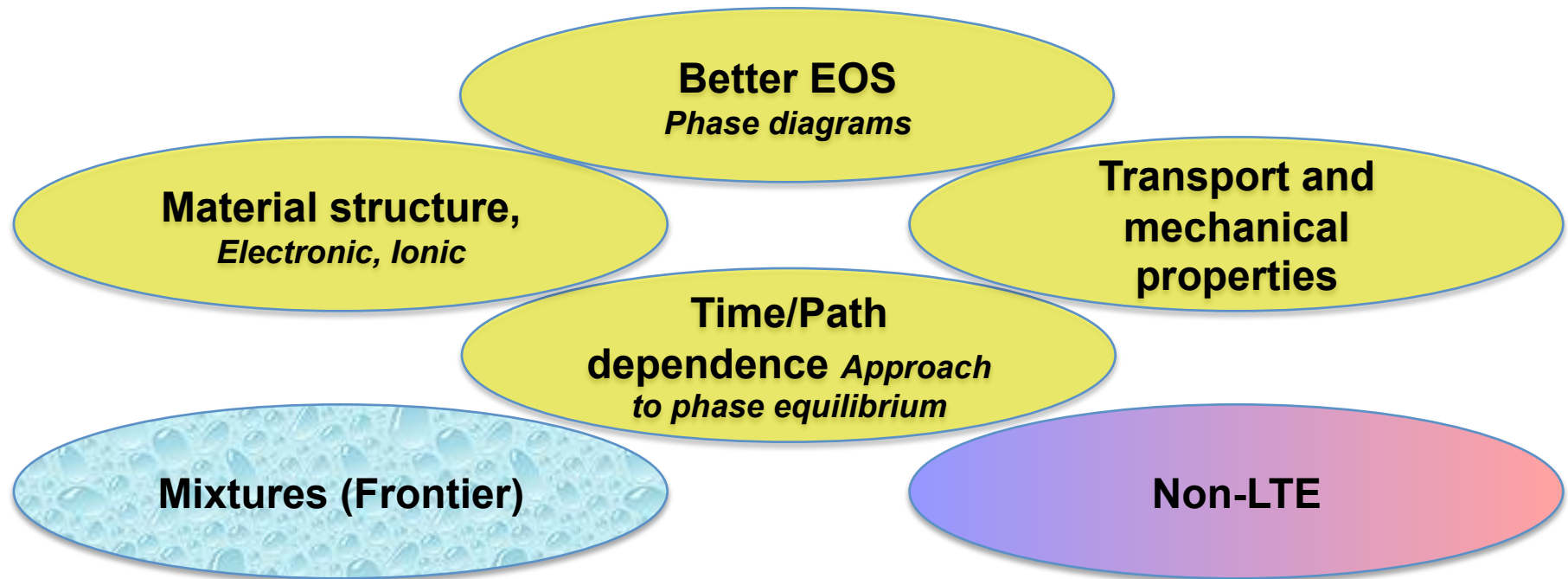


Properties of warm dense matter

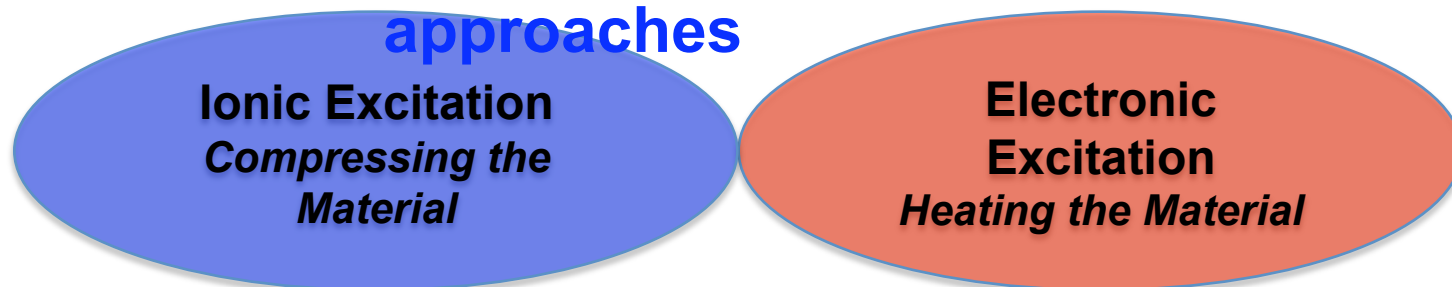
- solids at ultrahigh pressures or in ultrahigh magnetic fields
 - melting at extreme compression
 - phase transitions
 - transport properties
- Example application: Hypervelocity impact threats
 - satellite protection
 - killer asteroids

Warm Dense Matter

Scientific needs



Experimental approaches



Diagnosing WDM

Needs

Pressure
Density &
Temperature

Ionic & electronic
structure factor

Electrical
conductivity
Thermal conductivity
Viscosity

Time dependent
phenomena

Mixtures and
Heterogeneities

Approaches

Velocity Interferometry
Radiography
X-ray Thomson scattering
*Critical need for low
temperature measurements*

Diffraction
Spectroscopy

Develop

Picosecond to nanosecond
diagnostics

10 nm to 10 μ m spatial
resolution diagnostics

Theory & Simulation

I. Theory/Foundational – Finite-temperature many body theory

- a. Quasi-particle (QP) lifetimes, response functions; validity of QP concept
- b. Exchange and correlation at higher temperatures
- c. Finite temperature, time-dependent, Density Functional Theory (DFT)
- d. Self-consistent extension of equilibrium and non-equilibrium plasma formalisms to strongly coupled WDM regime

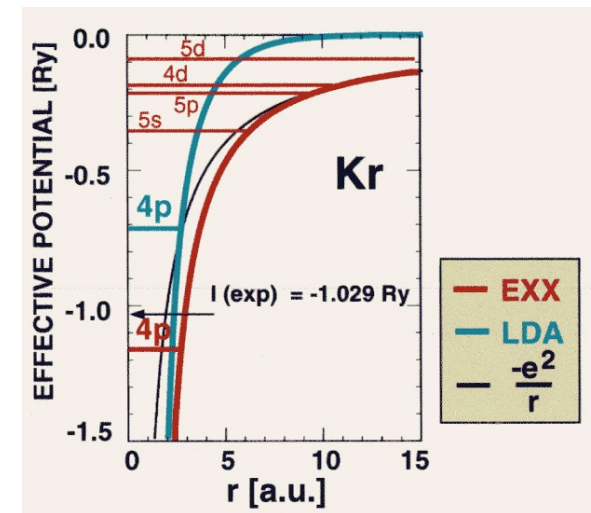
II. Modeling and Simulation

A. Accuracy

- a. Exact-exchange (EXX) extensions of DFT
- b. Coupled electron–ion dynamics
- c. DFT with high magnetic fields

B. Scale (larger systems)

- a. Orbital-free DFT representations with, without EXX
- b. Wave-packet MD



*LDA = Local Density
Approximation*

Planetary WDM

- Equations of state, phase transitions (including melting, liquid–liquid), mechanical & electronic properties
- Experiments into Gbar range guided, expanded by theory
- Systems
 - Hydrogen–helium mixtures
 - constitution and state of giant/supergiant planets
 - unmixing and thermal evolution
 - Iron and its alloys
 - cores of planets (due to abundance of Fe)
 - Oxides (minerals, rock; ceramics)
 - late-stage giant impacts (e.g., Moon-forming event)
 - cores of giant, supergiant planets
 - Molecular systems: water, methane, ...
 - “icy” giant planets; deep interiors of rocky planets; water worlds
 - link to life

Planetary Questions

- How was the Moon born?
 - violent planet formation
 - *properties of earliest planet (rock plasmas, heavy-hot atmospheres, magma oceans, ...)*
- How were Jupiter & Saturn formed?
 - control formation and evolution of Earth platform for life
 - *determined by interior structure (e.g., H_2 –He EOS for core)*
- Why is Saturn so warm?
 - *hydrogen–helium de-mixing*
- What is the nature of exoplanets?
 - hot Jupiters, supergiants, super-Earths, water worlds, carbon planets, ... ?
 - *equations of state, transport properties of planetary materials*

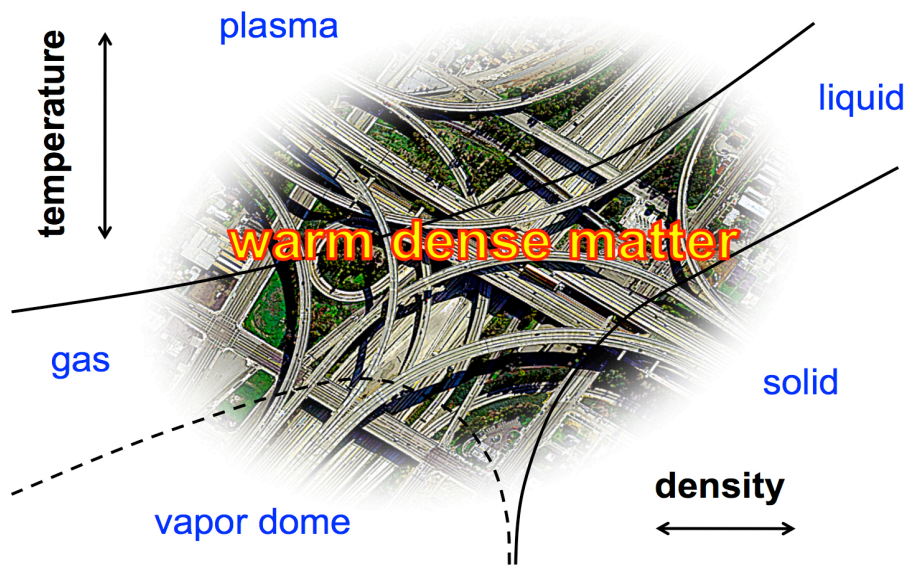


Figure 1. Warm dense matter occurs at the confluence of plasma, gas, liquid, and solid. The complicated interplay of the physical processes it shares with its neighbors creates a “malfunction junction” for our theoretical descriptions of warm dense matter and creates unique and exciting challenges for experiment and diagnostics.